A MEMS BODY FLUID FLOW SENSOR

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Abstract
To achieve *in vitro* flow rate measurements of biological fluids in such tasks as hematological studies and urinalysis, a MEMS flow sensor has been developed. Flow sensing is achieved by measuring the forced convective heat transfer from a thermal sensing element to the fluid. Currently, fluid flow down to 10 μl/min can be detected.

Keywords: Flow sensor, thermal sensing, King's Law

1. Introduction
Heat transfer is the most promising flow sensing principle for measuring very low flow rates (< 1 ml/min). Several thermal anemometer type sensors have been introduced in previous work [1-4]. Many use polysilicon thermistors as heating and temperature sensitive elements. Here, a metallic resistive sensing element is placed on a channel wall to sense flow rate. When operated in constant current mode, the convective heat transfer from this element to the fluid can be measured and correlated to flow rate.

2. Sensor Design and Fabrication
Sensors (Fig.s 1-2) consist of platinum resistors on a parylene membrane over a bulk micromachined silicon channel (1 mm × .5 mm × 8 mm). This structure prevents resistor contact with the fluid and possible issues with corrosion. Platinum is chosen as the sensor material for its stability, accuracy, and high temperature coefficient of resistivity (TCR). Additional packaging is performed to form fluidic connections using micromachined fluidic couplers [5].

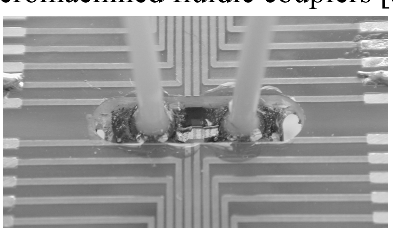

Fig. 1 Flow Channel & Fluidic Connections

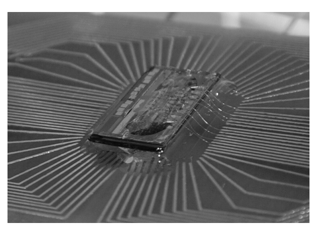

Fig. 2 Sensor Close-Up

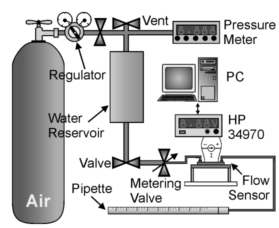

Fig. 3 Flow Testing Setup

3. Experimental
To determine flow rate, the sensor voltage is recorded under constant current (30 mA) while fluid is forced through the device using compressed air. The flow rate is adjusted by a metering valve and calibrated using a stopwatch and precision pipette (Fig. 3).

4. Results and discussion
Temperature calibration and transient behavior of the device under water flow and no flow conditions are shown in Fig.s 4-6. As expected, the device responds faster to

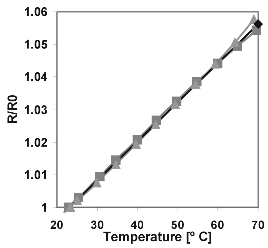

Fig. 4 Temperature Calibration

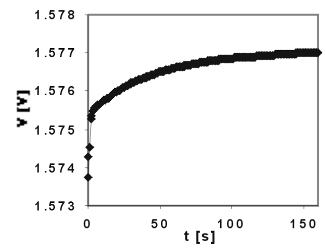

Fig. 5 Transient Response to No Flow

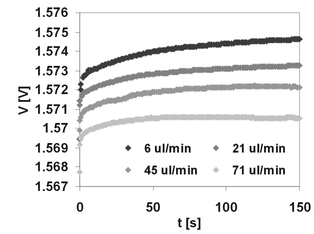

Fig. 6 Transient Response to Water Flow

higher flow rates. The transient response has two associated time constants, the first being less than 1 s and the second ranges from 10 to 60 s. These increase as flow rate decreases. The sensor response to flow rate was adjusted to remove the effects of ambient temperature fluctuations is shown in Fig. 7. Power consumption and overheat ratio were 36 mW and 1.9%, respectively. The sensor can resolve up to 10 μl/min flow. Commercial devices with such resolution are not currently available. These results are in agreement with behavior predicted by King's Law, $H(\nu) = A + B\, \nu^{1/2}$, where A = 0.8559, B = -0.878849, and n = 0.51 (Fig. 8).

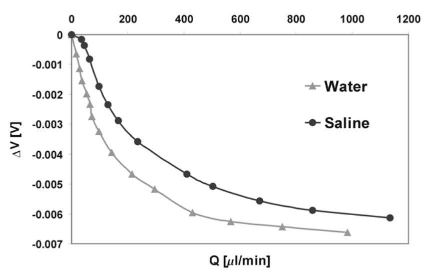

Fig. 7 Sensor Response to Flow

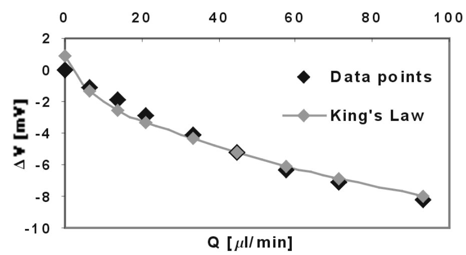

Fig. 8 King's Law vs. Experimental Results

5. Conclusion

A MEMS fluid flow sensor capable of detecting 10 μl/min flows has been demonstrated. Future work will include testing with different biological fluids, e.g. blood and urine, and various detergents. As many biological fluids contain particulate matter, the effect these have on measurements will also be examined.

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